THE RELATION OF THE INTERFERENCE TO THE PRACTICE EFFECT OF AN ASSOCIATION.

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The present paper gives the result of a further study of memory by the method described by the writer in this JOURNAL, Vol. V. No. 3. While the problem studied here has a close connection with that of the previous paper, it has been in part suggested by Dr. Münsterberg's "Gedächtnisstudien," Part I., *Beiträge*, Heft 4, to which reference was made before, and by experiment X. of Müller and Schumann's recent studies, "Experimentelle Beiträge zur Untersuchung des Gedächtnissses," (*Zeitschr. f. Psych. u. Phys. der Sinnesorgane*, Bd. VI., 2 and 3, p. 173, 1893.)

The statement of Dr. Münsterberg's problem is this: Can a given association function automatically while some effect of a previous and different association with the same stimulus remains? He concludes that it can, and that nerve currents do not divide like electric currents along different lines of association inversely as the resistance, but that a slight difference, one way or another, diverts the whole discharge in that direction. The experiments, as may be remembered, were made with some of the common habits of daily life, such as the opening of the door of his room, dipping the pen in ink, and taking the watch out of the pocket.

The statement of Müller and Schumann's problem is this: When a series of nonsense syllables has been learned till the first correct repetition is possible, and is then relearned to the same extent after a certain interval, will more repetitions be required if, in the meantime, the syllables of the series have been associated with another set of syllables? Two twelve-syllable series were learned at a given hour — one for a test, the other for a comparison experiment. The syllables of the test series were then united with twelve new syllables and made up into two series of such a nature that each syllable of the test series should enter into an association with a new syllable.

These were then learned. Two hours from the beginning of the experiment, the original test and comparison series were relearned. Schumann required for the first learning of the test and comparison series 13.1 and 13.0 repetitions, for the relearning 7.29 and 7.89, respectively. As the authors point out, the effect of the interference of associations is neither demonstrated nor disproved, since there is a source of error in the experiment. A considerable part of the work of learning a nonsense syllable series is spent in learning the syllables as such, and in this case the syllables of the test series are repeated about twice as many times as those of the comparison series before the final relearning of the two. The influence of the resulting greater familiarity with the syllables is, perhaps, consider-

able, and all that can be said is that the interference effect is not greater than this practice effect. There is also the fact that the new syllables contain some of the elements of those that were displaced.

The authors, however, suggest another reason, namely, that associative interference is a small and transient influence, and that so few repetitions only are needed to make the first association act to the exclusion of the other that the interference effect, if any, is not great enough to appear, and that Dr. Münsterberg's conclusion referred to above may here find additional evidence. The impressions of their subjects, however, favor the opinion that the interference of associations has considerable influence, especially at first in learning new series.

The experiments reported in two brief articles upon this subject by the writer, demonstrate the fact of interference and show the rate of its decrease with time, and that it is nearly a constant quantity after a little practice. In the case of these experiments we are, however, dealing with the formation of a new association to take the place of a previous one, and not with the revival of a still earlier one, so that they do not exclude the hypothesis that in the case of two associations connected with one stimulus, a slight superiority of one makes it appropriate the whole nervous discharge.

The common view is, perhaps, that a nervous excitation radiates in all directions with an intensity proportional to the permeability, which is in turn, within certain limits, proportional to the number of repetitions; and that the work of breaking up a habit is roughly proportional to the work of forming it. It is hard to say, from general considerations, what should be expected in this case. Interference, as an obstruction to association, is often injurious to the individual, and we might expect that some means of obviating the difficulty should have been developed. On the other hand, it makes for the stability of the associational system of the brain — the very great degree of which is usually not realized in view of the great variety and apparently erratic nature of the mental processes. Interference may, on the other hand, be due to a fundamental mechanical condition, over which natural selection can have no influence, and might, therefore, be expected to appear in simple cases, while in the more complex cases, means of avoiding it may have been developed.

These special questions may all be grouped under the more general problem of the relation of the interference to the practice effect of an association. To the solution of this question in its simplest cases the experiments of this paper aim to contribute. Four cases are possible. The interference effect may be greater than the practice effect; it may be equal to it, or less than it; or the relation of the two may be a variable one.

The experiments were made during March and April, 1894. The subject, M. E. B., was wholly ignorant of the object of the experiments during the entire time, and had no special interest in the matter, except to make as quick records as possible. M. E. B. had become very expert from practice in previous experiments. There had, however, been no practice for about a year, and the records at first are about seven per cent. longer than those of the year before, or those made at the end of the present series. All the records made are used in the tables.

For a fuller description of the experiments, and the precautions necessary, the reader is referred to the previous paper (this JOURNAL, Vol. V. No. 3). The experiment consists of sorting eighty cards into ten different piles, each to contain eight cards with the

same picture. In sorting the same pack a second time, a given card may be placed in the position which it originally occupied or in one of nine other positions. If the piles, in the second trial, are in the same positions as in the first, we have a simple practice effect; if in one of the nine other positions, the pictures on the cards enter into associations which necessarily exclude their former associations and we have an interference effect. The first table gives the result of a preliminary experiment, the plan of which will be seen to be like that of experiment X. of Müller and Schumann's studies. The conditions here are, however, much more simple. The influence of changing familiarity with the objects to be associated is minimal in this case, since the outline pictures used have become perfectly well known by long practice; and any given picture is associated first with one movement or position and then with another, and forms only to a small extent a member of a series. Let A_1 and A_2 denote two entirely different arrangements of the piles into which the same pack is to be sorted; also, let B_1 and B_2 be different arrangements of another pack, and D an entirely different pack. The numbers at the upper right hand corner indicate the number or order of the repetition. Each experiment consists of two parts, a test and a comparison set of records, and may be represented as follows:

I. II.

A_1 —— A_2 —— A_1^2 B_1 —— D —— B_1^2

The interval from A_1 to A_1^2, and from B_1 to B_1^2, is 315 seconds. A_2 and D were begun 120 seconds after A_1 and B_1 respectively. The length of time required for A_2 and D is such as to make the interval between A_2 and A_1^2, and D and B_1^2, also approximately 120 seconds (105-112). The packs represented by D had words printed at the top instead of outline pictures. These are about as difficult to sort as A_2, and were used to make the amount and distribution of the work done in the interval of II. approximately equal to that done in the interval of I., so that no difference of nervous excitement or fatigue might disturb the results. After a little practice the variations of the experiment are very small. This is probably due to the uniform attention which can be given to it, since the conditions are natural and the work is rather pleasantly exciting. The material is also quite regular.

There are twenty-four records for each value given in Table I., that is, 144 in all. The middle record is given as the most probable value, rather than the arithmetical average. What corresponds to the probable error of the average was obtained by taking the differences between the middle record of the whole and the middle records of the upper and lower halves respectively and dividing by $\sqrt{24}$. The middle record of the whole is, of course, the average of the 12th and 13th records. The distribution of errors is quite asym-

TABLE I.

	A_1	A_2	A_1^2	B_1	D	B_1^2
Middle record	60.5	83.1	75.6	60.2	90	52.7
Range of variation	+1.15, —.7	+.95,—1.42	+1.25,—1.52	+.84,—.88	+1.88,—1.8	+1.14, —.95

metrical in A_1, A_2, A_1^2, and B_1^2, but in the reverse direction in A_2 and A_1^2 from that which we usually expect in psychological measurements.

The interference effect of A_2 upon A_1^2 will be found by taking the difference between A_1^2 and B_1^2, the time which would have been required by A_1^2 if A_2 had not been sorted. This is 22.9 seconds, which is very nearly equal to the interference effect of A_1 upon A_2, —22.6 seconds. The effect is evidently quite marked and there is not a single negative result, either in these or the subsequent records. We may make three hypotheses with regard to the nature of the process: first, that A_1 and A_2 efface each other and that consequently the sorting of A_1^2 takes place under nearly the same conditions as A_1, and hence requires less time than A_2; or, secondly, that the practice effect is not effaced, but remains unchanged as a tendency, and that the difference between A_2 and A_1^2 is simply due to the practice effect which remains over from A_1. Thirdly, we might have partial effacement and partial permanence of the individual associations. If the first hypothesis is true, then a totally different arrangement, A_3, should have the same advantage as A_1^2. If the third is true, A_3 would require less time than if there were no effacement. Evidence in connection with Table II. will be given to show that the second hypothesis is the true one. General considerations also support this view. Any given idea enters into a great variety of combinations, and if its different associations tended to efface each other, we could not recall at will the different associates. As has been pointed out before, we have difficulty in these cases, due to the interference of association, and must often wait till the strength of the interfering association diminishes before we can get the one we want; but the fact that we can get it at all shows that it was not effaced.

This preliminary experiment does not, however, give us the relation between the interference and practice effect even as far as it goes; and a much greater number of repetitions of each association is desirable. As far as we know yet, practice may be more or less permanent and have a greater or less influence than interference. Further, the relative value of the divisions within the range of variation of the experiment ought to be known, or something like a zero method adopted for studying the subject. To meet these requirements the following experiment, which is the one upon which this discussion is based, was made. Using the same notation as before, the plan of the first part of the experiment may be represented as follows:

$$A_1^1\ A_2^1\ A_1^2\ A_2^2\ A_1^3\ A_2^3 \ldots\ldots\ldots\ldots A_1^8\ A_2^8$$

and that of the second, or comparison part, by

$$A_1^1\ B_1^1\ A_1^2\ B_1^2\ A_1^3\ B_1^3 \ldots\ldots\ldots\ldots A_1^8\ B_1^8.$$

A pack was sorted every three minutes, so that each part of the experiment required forty-eight minutes. Consider any two corresponding records in part I., as (A_1^6 and A_2^6). The memory work done upon each association of A_1^6, before it is itself sorted, is 5×8, or forty practice associations, and also forty interference associations. The interference associations have an advantage in being a *little* more recent. We know, from the experiments of the previous paper, approximately the rate of decrease of interference at this stage of practice for this subject. The difference between the interference for a two and an eight minute interval is only 3.49 seconds. On the whole, we should expect the accumulated advantage of the interference associations to come within five seconds. Accordingly, if the practice and interference effects of an association are equivalent, we should expect that A_1^6 will require from one to five seconds

longer than A_1^1, which we find to be the case, if we take as a more probable value of A_1^1, 61, the average of 58.53 and 63.48, or if we take the middle records. Similar reasoning applies to all the members of the A_1 series. A_2^6, on the other hand, has been preceded by forty practice associations and forty-eight interference associations. As regards time, the interference associations have the same advantage as in the case of A_1^6. We should, accordingly, expect to find the records of the A_2 series a little longer than those of the A_1 series.

All the precautions found necessary in the experiments of the previous paper have been observed here, and in addition, since it was necessary to use the same cards twice in these experiments and the number of repetitions was so great, an interval of a couple of weeks was observed before the same pack was used again. The arithmetical average and the usual probable error are given in Tables II. and III., since the number of records seemed too small for the same treatment as those in table I. Each average is the average of eight records. The middle records of the A_1 series, that is, the average of the fourth and fifth records, are also given, since this series is especially important.

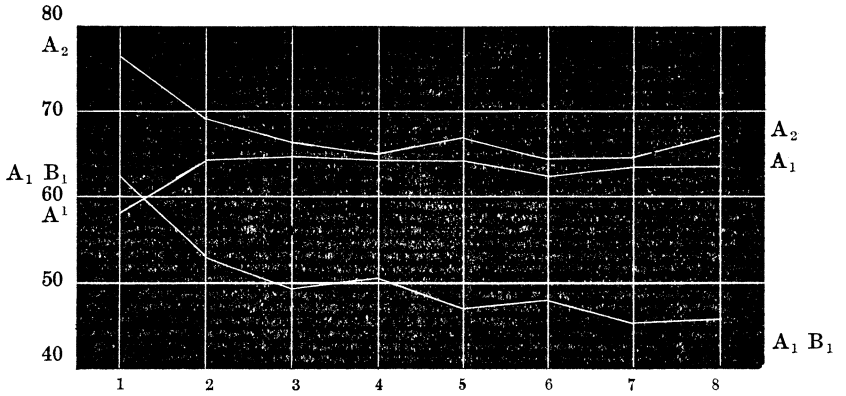
TABLE II.

No. of packs sorted.	1	2	3	4	5	6	7	8
A_2 Series	76.63	69.15	66.3	64.53	66.61	64.5	64.1	67.08
P. E. Av.	±1.55	± .728	± .95	±1.03	± .982	±1.087	±1.37	±1.22
A_1 Series	58.53	64.95	65.30	64.05	63.98	62.68	63.85	63.35
P. E. Av.	± .807	± .989	±1.47	±1.38	± .906	±1.00	± .713	±1.36
A_1—B_1 Series	63.48	52.85	49.86	50.6	47.2	47.95	45.52	45.52
P. E. Av.	±1.27	±1.35	±1.07	±1.06	± .893	± .969	± .129	±1.1
Middle Records of A_1 Series	59.4	63.7	62.7	63.1	63.3	62.4	63.	62.4

The records of the A_1 and B_1 sets of the comparison experiment A_1 B_1, correspond closely and are united in the averages.

The first record of the A_1 series is smaller; and that of the A_1 B_1 series is greater than we should expect at this stage of practice. The average of the two, 61 seconds, is probably more nearly correct. The first middle record of the A_1 series (59.4 seconds) is, contrary to the usual rule, larger than the arithmetical mean, which indi-

cates that this mean is too small. The middle records of the A_1 series are, with this exception, smaller than the corresponding averages. They are quite uniform and are perhaps to be preferred.



The facts of Table II. may be seen more easily in the accompanying cut. A_2 A_2, A_1 A_1, and A_1 B_1—A_1 B_1 are the curves which correspond respectively to the A_2, A_1, and A_1 B_1 averages of the table. The abscissas represent the number of repetitions of each association, which varied from one to sixty-four. They may also represent the number of packs sorted, *i. e.*, from one to eight, and, since this was done at regular intervals, they may also represent the time. If we select any point along the abscissas, as, for example, the last, we see at once that under approximately the same conditions the preceding fifty-six practice associations reduce the record to 45.52, and that fifty-six practice and fifty-six interference associations so balance each other that the record is very nearly what it would be if they had not been made. It is, of course, a little higher, but this can be explained by the fact that the interference associations are a little more recent. The total interference effect of the sixty-four associations, as we know from eight tests taken at the end of the A_1 B_1 series, makes the record 83.4 seconds. In general, we may say that the line A_1 A_1 would be above or below its present position if the interference effect were not approximately equivalent to the practice effect, but either greater or less. If we assume that the practice effect is proportional to the number of repetitions, and that the interference effect is equal to the practice effect, multiplied by a certain constant, greater or less than unity, the line A_1 A_1 would evidently be straight, though making a certain angle with its present position. With the same assumption regarding practice and the number of repetitions, if the interference effect sustains a variable relation to the practice effect, A_1 A_1 would evidently be curved. If, on the other hand, the practice effect is not directly proportional to the number of repetitions, but is some other function of it, the last two assumptions about the relation of interference to practice being maintained, A_1 A_1 would have a curvature respectively similar to or different from that of the true practice curve. The true practice curve may, of course, differ considerably from the usual practice curve obtained by experiment, since the mechanical conditions of the experiment may prevent any reduction in time and yet the result of practice

show itself by a greater permanence of the associations. The true practice and interference curve should represent the energy of the associations, which is here the thing considered. If we take the interference records of our experiment as even approximately proportional to the true interference effect, it is evident that the first eight repetitions have relatively much greater influence upon the associative tendency than the subsequent fifty-six. Whatever the relation between true practice and the number of repetitions may be, the fact that A_1 A_1 is nearly parallel to the axis of abscissas, and is nearly straight from 2 to 8, and is, besides, but slightly above the level of records which have been preceded by neither practice nor interference associations, can only be explained by assuming the equivalence of the practice and interference effects. With the assumption of a variable relation of interference to practice, we might explain the fact that A_1 A_1 is straight and parallel to the axis of abscissas on any assumption of the relation of practice to the number of repetitions, but not its present position.

The total number of repetitions is about twelve times that required for the first free repetition from memory, since the cards can be thrown without reference to the piles when about two-thirds of the first pack has been sorted. The result is accordingly true for quite an advanced stage of practice.

There are, however, certain sources of error in the experiment which should be mentioned. With continued work most individuals experience at first an exaltation, then a depression of power. With the present distribution of the work, and this stage of practice, the variations for M. E. B. from these causes are very small, if demonstrable at all. In a previous experiment, tests at the beginning and end of an hour's work gave the records 57.05 and 56.30 respectively. The average of twelve hours, in which the kind and distribution of the work were very much like that of experiment II., does not show any such fluctuations. With two exceptions, the experiments of Table II., as well as those just referred to, were made about 8 A. M. The other two were made at what the subject felt were favorable times in the afternoon. All that is important is to take a time in which the subject's energy is not liable to variation.

The question regarding the nature of the nervous process, discussed in connection with experiment I., can now be answered definitely. If the series A_1 A_1 and A_2 A_2 do not simply balance but actually efface each other, any other arrangement of the same cards A_3, would have the same advantage as A_1^8 or A_2^8. At the end of four experiments a test was made with A_3. The average of the records is 91.6 seconds, showing a great amount of interference. Hence, while different associations with the same stimulus interfere, they do not efface each other, but retain an individual existence. They probably do not even partially efface each other, as is shown by the following fact: The total interference effect of the sixty-four repetitions of the A_1 B_1 series gives a record of 83.4 seconds as an average of eight experiments. The tests by which the interference is shown were made as regular continuations of the experiment. While considerable variation must be allowed in the case of 91.6 seconds, it does not seem probable that the interference of the A_1 A_2 series is any less than that of the A_1 B_1 series, as would be expected if the contradictory associations partially effaced each other. This last matter is, however, not quite certain. In the A_1 A_2 series there are two associations to interfere; in A_1 B_1 only one. Furthermore, a little more work is done upon the A_1 A_2 series, the result of which we may, perhaps, suppose would be

to make the associations A_1 and A_2 stronger than they would be without interference. These facts leave room for the possibility of a small partial effacement. The results of previous experiments, on the other hand, support the view that the interference effect of two or more associations is not greater than that of one, other things being equal; since, if a succession of different arrangements, A_1, A_2, A_3, A_4, etc., are used, the time of A_2 is considerably longer than that of A_1, but the time of A_3, A_4, etc., is nearly the same as A_2, and the fact that the interference is greater in the A_1 A_2 than in the A_1 B_1 series might meet the demands of the second consideration, if they are just.[1] It seems probable, therefore, that there is not even a partial effacement of the associations.

In previous experiments the amount of interference remained quite constant, even while there was considerable change in general practice. We may explain this by assuming that the practice effect for that particular part of the process represented by the interfering associations attained its full measure very soon. While there is no great difference in general practice noticeable between experiments I. and II., there is considerable with regard to the interference effect. This may be due to the greater complexity of this part of the process in these experiments. It even seems probable that if experiment II. had been made at the stage of practice of experiment I., the records would have shown that the interference effect is greater than the practice effect. The test of the matter is of course to be made when the subject is in good training and capable of taking advantage of or mastering the practice and interference tendencies with something like uniform effectiveness. The amount that A_1^2 is above A_1 especially shows differences in the two groups of experiments gathered up in Tables I. and II., being 15.1 seconds in the first as compared with 3.95 seconds, or at most, 6.45 seconds, if we take the average of A_1, Table II., at 58.53 seconds. A third group of experiments was accordingly made exactly like the first. The result is given in Table III. There are ten records for each average.

TABLE III.

	A_1	A_2	A_1^2	B_1	D	B_1^2
	56.80	72.32	63.28	55.37	82.06	47.06
P. E. Av.	± .987	±1.1	± .807	± .930	±1.28	± .589

The intervals are not quite the same, but the difference is not such that we can expect much change in the results from this source as compared with Table II. The close correspondence with Table II. is sufficiently evident. Here, as in Table I., A_2—A_1 very nearly equals A_1^2—B_1^2, the differences being 15.52 seconds and 16.22 seconds respectively, showing that the interference effect of A_2 upon A_1^2 is the same as that of A_1 upon A_2.

For the proper estimation of the results of measurements, we must know the range of variation and the scale of equal values of

[1] AMERICAN JOURNAL OF PSYCHOLOGY, Vol. VI. No. 2, p. 272.

the instrument we employ. The shortest record made in experiment II. in the A_1 B_1 series is 36.6 and the longest, with this series, that is, in the interference experiment, 101 seconds. The difference of the average of these interference tests, 83.4 seconds, and the last average of A_1 B_1, 45.52 seconds, may be called the average range of this experiment. This is not, however, the maximum average range, since the minimum record suggests the possibility of a still lower average, and we have an interference average of 91.6 seconds. The lower limit is fixed by the maximum rapidity of handling the cards and the process of discrimination and choice. The upper limit is not so well defined and probably exceeds the time which would be required if the memory of the positions did not co-operate at all—which would seem a natural limit—since the subject looks in the wrong direction more than he would if the matter were left to chance.

To get some estimate of the value of the divisions of the range of variation, we may ask: What is the variation which equivalent tendencies of association produce above and below sixty-one seconds?—the record made when no previous associations are present. The total practice effect of the first fifty-six associations of the A_1 B_1 series reduced the record to 45.52 seconds. From the general course of the curve we can assume with only a small error that the effect of sixty-four associations would have been the same. The total interference effect of sixty-four associations gives an average record of 83.4 seconds. The difference above sixty-one is 22.4 seconds, below 15.52 seconds for these equal forces. To get a comparison of smaller variations, let us assume that the records of the first paper[1] are comparable with those of experiments II. The justification for this is that the stage of general practice is about the same, and especially that the interference with the 120 seconds interval is nearly the same in both cases—namely, 13.57 seconds and 15.63 seconds. The practice effect of eight associations, with a 300 seconds interval, is 8.15 seconds. The interference effect (from Table III. of the above-mentioned paper) is about twelve seconds. The ratio $\frac{8.15}{12}$ is nearly equal to $\frac{15.52}{22.4}$. Accordingly, as measured by the variations in the experiment, the practice effect is two-thirds the interference effect; although, as measured by a method in which there was only a slight change in the records, they are equivalent. The latter is of course the true measure and shows that the variations above are relatively greater for the same associative tendency, in these special cases, in the ratio of three to two. These records are not sufficient to enable us to map out the scale more in detail.

To summarize the results briefly: We have shown that under the simple conditions of this experiment, the interference effect of an association bears a constant relation to the practice effect, and is, in fact, equivalent to it. As regards the nature of the process, it has been shown that we are dealing with the interference of still persisting associations and not with the results of their effacement.

To estimate the results correctly we must refer to the conditions of the experiment. The cards are sorted with the greatest possible speed. Every assistance the memory of the positions can give is utilized. All conditions, except the memory factor, are approximately the same in each test; and the variations in the records are due to the latter. As has been stated before, psychophysic processes, higher than simple successive association, seem to be

[1] AMERICAN JOURNAL OF PSYCHOLOGY, Vol. V. p. 361.

excluded. If at the end of the A_1 A_2 series of tests M. E. B. tries to recall the positions of both A_1 and A_2, this can usually be done, though with difficulty. Considerable time would be required to fix the twenty positions in memory, especially since they are contradictory. The associations are here in balance, and in sorting with the greatest possible speed, it is nearly the same as if there had been no previous associations; nevertheless, if the subject takes time to think, every card can usually be placed correctly, from memory. This is another proof that the associations persist and have not been effaced, and also that in sorting with the greatest possible speed, higher processes are excluded, but that such may modify the result greatly if the work is done deliberately.

Since we know what the relation of practice to interference is in a simple case, we have the basis for understanding the changes of the results when other factors enter.

The nervous system has, as is well known, inherited tendencies of growth and adjustment to external circumstances. Perhaps the simplest of these, for the organization of nervous activity, is the tendency of nerve currents to run from one impression to the next succeeding. This is modified in many ways by special tendencies of higher order, which may be classed as fundamental practical adjustments, or practical interests. If these are given an opportunity to influence the results, we are not dealing with associations *per se*, but with these as modified by other more powerful forces. These means of avoiding interference, however, require time and energy. More time is required, otherwise we might expect them to assist us when we act with the greatest possible haste. More energy is required, since the process is more complex and the work of analysis, which is the incorporation of parts of one process in another, is proverbially difficult. There are, besides, great numbers of secondary tendencies by which simple successive association is transformed. Moreover, where the conditions are more complex than in this experiment, certain elements may enter and change the results. A person who speaks several languages finds that the words of the same language tend to be recalled together. Some persons, also, know and can use two different systems of shorthand. In these cases the elements associated are used as members of a group, for the exclusive employment of which there seems to be a strong tendency. The inconvenience of interference is thus to some extent avoided in these cases, but probably only by proportionate expenditure of energy.

The theory as to the character of nervous associations, referred to in the beginning, namely, that a nervous discharge does not radiate into all lines of association, but is wholly appropriated by the association which has a momentary advantage, is evidently not supported by the results of these experiments. The fact that the approximate proportionality of the interference and practice effects of an association can be demonstrated in any case in which simple successive association is utilized to the full extent, leads us to suspect that where facts seem to correspond with this theory, some accessory associations have been developed to bring about the result.

In conclusion I wish to acknowledge my indebtedness to Dr. Sanford for valuable suggestions and to my wife, who has greatly aided me in this study.